Although it can be applied to any tone ringing signalling operations, the present invention and the problems on which it is based are explained with respect to a tone ringing signalling operation for an interphone.

To ensure fault-free signalling of tone ringing, a tone ringing signalling operation has to meet certain requirements. On the one hand, signalling is required to take place only as from a certain minimum modulation (level condition) and, on the other hand, only in response to excitations in a fixed frequency window (frequency condition).

Satisfying the level condition is generally ensured by hardware, whereas satisfying the frequency condition is a task for the software. Failure to satisfy one or both conditions leads to incorrect ringing signalling (for example, no signalling or late signalling when there is a valid ringing signal, ringing signalling without a ringing voltage, etc.).

Superposed interferences of the AC ringing voltage have a great influence on the correct operation of tone ringing frequency detection. However, detection of frequencies affected by interference is not a trivial problem.

Figure 3 shows an illustration of how a ZC signal (ZC = Zero Crossing) is derived from the sensed tone ringing voltage.

In Figure 3, the time t is plotted on the x-axis and the tone ringing voltage $U_T$ or the ZC signal ZC is plotted on the y-axis. The tone ringing voltage $U_T$ is, in this case, assumed to be a pure sinusoidal AC voltage (solid line at the top of Figure 3).

To permit tone ringing frequency detection, the rectified tone ringing voltage $U_T$ (broken line at the top of Figure 3) is applied to a comparator (not represented). The output of the comparator is connected to a processor, which processes the ZC signal.

As shown, the comparator carries out a comparison of the rectified tone ringing voltage $U_T$ with a threshold S. Each time the rectified tone ringing voltage $U_T$ passes through this threshold in a rising sense, the ZC signal has a falling edge. With every subsequent zero crossing, the ZC signal has a rising edge. Consequently, a certain hysteresis is built in.

The frequency f of the tone ringing signal is obtained in this simple case as t*= 1/2f, where t* is the time interval between two successive rising or falling edges of the ZC signal.

Figure 4 shows an illustration of a ZC signal without interference, with a differing amplitude of the tone ringing signal.

As Figure 4 reveals, the pulse duty ratio of the ZC signal is highly variable, depending on the position of the comparator threshold S or signal modulation of the tone ringing signal.

Since, however, to measure the period duration or frequency f, triggering is usually in response to the rising or falling edge of the ZC signal, a determination of the frequency f is possible independently of the pulse duty ratio of the ZC signal.

In actual systems, it must be expected that the tone ringing signal is not a pure sinusoidal oscillation, but has superposed periodic and/or a periodic components. These superposed components become noticeable, in particular, whenever the amplitude of the interference is greater than the hysteresis of the ZC detection circuit.

A measure of the insensitivity to such interferences is the interference immunity to external signals. Superposing of interferences over the ZC signal leads to signal variations which are shown in Figure 5 for an interference-affected ZC signal with a differing pulse duty ratio.

The fastest possible evaluation of such interference-affected ZC signals is not trivial. To determine the fundamental oscillation, the interferences must be ignored. With an unfavorable pulse duty ratio, however, it is no longer possible to distinguish between interference pulses and the useful signal.

Systems which blank out pulses or groups of pulses are known. These have, on the one hand, the disadvantage that additional resources are required (for example, a second time base for the blanking out of the interferences). On the other hand, such systems actually carry out a kind of undersampling of the ZC signal by blanking out certain times. If, in this case, the blanked-out time interval is no longer negligible in comparison with the times to be measured, measuring errors occur.

This is illustrated in Figure 6, which shows errors during the interference suppression of the ZC signal which arise due to simple blanking out of the interferences. The blanked-out time range is shaded gray. $T_M$ designates the measuring interval.

In case a) of Figure 6, a ZC signal without interferences is obtained; the tone ringing frequency f is correctly determined.

In case b) of Figure 6, a ZC signal with interferences is obtained; the tone ringing frequency f is correctly determined.

In case c) of Figure 6, a ZC signal without interferences is obtained; the tone ringing frequency f is not correctly determined, since parts of the useful signal here are wrongly blanked out. In other words, an invalid signal not affected by interference is wrongly determined as valid.

Consequently, with the known approaches presented above, the fact that reliable interference suppression is not possible in all cases has been found to be disadvantageous.

## SUMMARY OF THE INVENTION

The method and apparatus according to the present invention for determining tone ringing frequency have the advantage over the known approaches to a solution that, by contrast with known blanking-out methods, reliable interference suppression is possible in spite of radio-frequency interferences on the ZC signal.

The idea on which the present invention is based is that each time interval between a falling edge and a rising edge of the ZC signal is evaluated and an evaluation start time and an evaluation stop time are determined on the basis of a limit value, the evaluation interval determined in this way being a measure of the frequency sought.

According to a preferred embodiment, a monitoring time window for the frequency determination is defined and the measurement is discontinued if the time measured since the evaluation start time lies outside the monitoring time window.

According to a further embodiment, the time duration limit value is defined as a constant.

According to yet another embodiment, a value which is as great as possible is defined for the time duration limit value, with which the attempt to define the evaluation start time is commenced. This value is reduced in accordance with a predetermined algorithm if no evaluation start time can be defined after a certain time.

Additional features and advantages of the present invention are described in, and will be apparent from, the following Detailed Description of the Invention and the Figures.

## BRIEF DESCRIPTION OF THE FIGURES

Figure 1 shows an illustration of an embodiment of the method according to the present invention when applied to an interference-affected ZC signal with differing pulse duty ratio.

Figure 2 shows a state diagram of the embodiment of the method shown in Figure 1.

Figure 3 shows an illustration of how a ZC signal (ZC = Zero Crossing) is derived from the sensed tone ringing voltage.

Figure 4 shows an illustration of a ZC signal without interference, with a differing amplitude of the tone ringing signal.

Figure 5 shows an illustration of an interference-affected ZC signal with a differing pulse duty ratio.

Figure 6 shows an illustration of the problem which errors occur during the interference suppression of the ZC signal by simple blanking out of the interferences.

## DETAILED DESCRIPTION OF THE INVENTION

Figure 1 shows an illustration of an embodiment of the method according to the present invention when applied to an interference-affected ZC signal with a differing pulse duty ratio.

In the case of this embodiment, individual time ranges are not ignored for the determination of the fundamental wave, but instead all partial events are taken into consideration. This is on the assumption that the interferences which are

superposed on the ZC signal are at a higher frequency than the frequency f to be determined.

In other words, a continuous measurement of the respective time duration between the adjacent rising and falling edges of the ZC signal takes place. The frequency of the fundamental oscillation is then derived from these partial events. This embodiment presupposes that the direction of the edge (falling or rising) of the ZC signal can be successively reversed to produce an interrupt.

The time durations of individual partial measurements $m_i$, $m_j$ are compared with a predetermined limit value $t_g$ which, in this example, is constant. If the time duration of a partial measurement is greater than the limit value $t_g$, the start condition is satisfied; i.e. an evaluation start time $t_1$ is defined, if a measured time duration is greater than or equal to the time duration limit value $t_g$, the evaluation start time ($t_1$) being the instant of the subsequent edge. At the same time, the phase position of the ZC input signal is determined ("0" = l(ow) or "1" = h(igh)). In Figures 1a) and 1b), this phase position is "0", and in Figure 1c) it is "1".

The stop condition is the next-but-one long ZC signal cycle with the same phase position. Consequently, an evaluation stop time $t_2$ is defined if a measured time duration with an identical ZC signal value to the next-but-one instance is greater than or equal to the time duration limit value $t_g$, the evaluation stop time $t_2$ being the instant of the subsequent edge.

The timer, or time generator, from which all the times are derived, runs freely after the start condition. The time which the timer requires for running through once must in this case be greater than the monitoring window for the ZC signal, which can be defined by a lower time limit $T_u$ and an upper time limit $T_o$.

If no further interrupts are detected in this monitoring window, the measuring operation is discontinued and the measuring function is returned to the basic state (i.e., the frequency is very low).

The determination of the frequency f sought takes place on the basis of the measured time difference between the evaluation start time $t_1$ and the evaluation stop time $t_2$, where $1/f = t_2 - t_1$.

Expedient parameters for the determination of $t_g$ are, for example:

| | |
|---|---|
| comparator threshold on ($V_{on}$) | 17.5 V |
| comparator threshold off ($V_{off}$) | 6.5 V |
| minimum frequency ($f_{min}$) | 20 Hz |
| maximum frequency ($f_{max}$) | 60 Hz |
| interfering voltage ($U_{ST}$) | 6 $V_S$ |
| ringing voltage ($U_R$) | 32 $V_{eff}$ |

Figure 2 shows a state diagram of the embodiment of the method according to the present invention as shown in Figure 1.

In Figure 2, I designates an initialization routine, in order to put the system into a basic state G. Starting from this basis, the time interval between the adjacent rising and falling edges of the ZC signal is measured, until an interval with t greater than or equal to $t_g$ is found.

Then, the timer is started (START) at an evaluation start time $t_1$, which is the instant of the subsequent edge.

At the evaluation stop time $t_2$, when a measured time duration with the same ZC signal value to the next-but-one instance is greater than or equal to the time duration limit value $t_g$, the evaluation stop time $t_2$ being the instant of the subsequent edge, the timer is stopped again.

The various instances at which a measured time duration is greater than or equal to the time duration limit value $t_g$ are designated here by I, II and III. The left-hand loop is for the case of an L starting phase, the right-hand loop for the case of an H starting phase. The respective loop with the designation 1) refers to either the time condition or the phase condition not being satisfied.

If the measured time interval T is within the allowed time window $[T_u, T_o]$, the frequency f determined from it is valid, and the system reverts to the basic state G. Otherwise, the system reverts to the state I.

Although the present invention was described above on the basis of a preferred exemplary embodiment, it is not restricted to this but can be modified in a variety of ways.

In the case of small measuring ranges, as in the case of the above example, the parameter $t_g$ can be defined as a constant. The time interval of the undisturbed

signal component in the case of the highest valid frequency $f_{max}$ must be greater than $t_g$. In the case of greater measuring ranges and a constant ZC input signal (i.e., the frequency does not change during the measurement), the measurement can be commenced with the greatest possible $t_g$. If no start condition is found, the parameter $t_g$ is reduced until a start condition is found.

Although the present invention has been described with reference to specific embodiments, those of skill in the art will recognize that changes may be made thereto without departing from the spirit and scope of the invention as set forth in the hereafter appended claims.